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Original Article

Physico-Chemical and Bacteriological study of Landzu stream using IDW method of interpolation

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ABSTRACT

This study assessed the physicochemical and bacteriological quality of Landzu Stream in Bida, Niger State, Nigeria, using an integrated approach that combined laboratory analyses with Geographic Information System (GIS) techniques. Water samples were collected from three locations along the stream, upstream, midstream, and downstream, to evaluate spatial variations in water quality and identify potential pollution hotspots. Physicochemical parameters analyzed included pH, temperature, sodium (Na^{+}), magnesium (Mg^{2+}), and calcium (Ca^{2+}), while bacteriological assessment focused on *Escherichia coli*, *Shigella spp*., and *Klebsiella aerogenes* using the Multiple Tube Fermentation method following standard procedures. Results showed that pH values (7.04–7.15) and concentrations of major ions were within World Health Organization permissible limits, indicating minimal chemical pollution. Stream temperatures (28.6–29.3 °C) reflected prevailing tropical conditions. In contrast, bacteriological analysis revealed the presence of *Shigella spp*. (42.9%), *E. coli* (28.5%), and *K. aerogenes* (28.5%), suggesting faecal contamination likely linked to domestic and agricultural activities. Most Probable Number counts increased downstream, indicating contaminant accumulation along the flow path. GIS-based spatial analysis highlighted the downstream segment as a pollution hotspot. Although physicochemical parameters met acceptable standards, bacteriological contamination renders the stream unsuitable for direct human consumption without treatment. Continuous monitoring, improved waste management, and public awareness are recommended. The study demonstrates the effectiveness of GIS as a valuable tool for surface water quality assessment and management in semi-urban environments.

Keywords: Water quality assessment; Bacteriological contamination; Physicochemical parameters; Geographic Information System (GIS); Landzu Stream

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INTRODUCTION

Water covers approximately 71% of the Earth's surface and functions as a universal solvent essential for life. In its pure state, it is clear, transparent, nearly colourless, odourless, tasteless, and free from bacteria and suspended particles, with a freezing point of 0 °C, a boiling point of 100 °C, and the chemical formula H_2O. Water occurs naturally in three physical states: liquid, gaseous (water vapour), and solid (ice) [1].

In rural Nigerian communities, wells constitute a primary source of drinking and domestic water, while streams and rivers are extensively used for residential and agricultural purposes [1] . Despite the availability of water resources, access to safe and potable water remains limited, particularly in rural areas where sources are frequently contaminated by bacteria, suspended particles, and other pollutants [2],. This contamination poses substantial risks to human health and the environment, underscoring the need for effective water treatment and management strategies.

Streams in Nigeria are especially vulnerable to pollution due to inadequate protection and proximity to anthropogenic activities such as washing, waste disposal, mining, agriculture, and industrial operations [2]. Consequently, freshwater resources face increasing threats from degradation, reflecting their high susceptibility to environmental deterioration [1] .

Nigeria is classified among countries with polluted water supplies, partly due to poorly coordinated operations of government agencies responsible for water management [4]. Insufficient treatment and declining water quality promote the spread of waterborne diseases, a problem that is particularly acute in rural communities where potable water quality is often overlooked. Surface waters are commonly contaminated with microbes, heavy metals, plastics, chemicals, faecal matter, urine, and debris, with coliform bacteria being the most prevalent indicators of contamination [1], [5]. Elevated microbial loads and abnormal physicochemical parameters adversely affect public health and economic productivity, making routine water quality assessment essential for controlling harmful substances and microbial proliferation.

Research on surface water pollution is particularly relevant to the Landzu Stream in Bida, where municipal sewage [6], agricultural runoff, and urban discharges substantially degrade water quality. These anthropogenic inputs pose serious risks to aquatic ecosystems and downstream users. Moreover, improvements in contaminated surface waters may not be immediate even after pollution sources are controlled [7]. Continuous monitoring and the implementation of effective protective measures are therefore imperative.

Geographical Information Systems (GIS) have become indispensable tools for environmental monitoring, especially for mapping and analysing water quality data. By integrating spatial information with water quality parameters, GIS facilitates the identification of patterns and trends that may not be discernible using conventional assessment approaches [15].

MATERIALS AND METHODS,

Study Area Background and Description

Landzun Stream (indicated on the map in Figure 1) is a major natural water body located near Bida, the administrative headquarters of Bida Local Government Area in Niger State, Nigeria. Bida lies between latitudes 9°05′N and 9°15′N and longitudes 6°00′E and 6°15′E, within the Southern Guinea Savanna ecological zone, which is characterized by a tropical climate with distinct wet and dry seasons. The stream traverses the central part of the town, serving as an important drainage channel and a primary water source for surrounding communities.

The Landzun Stream originates from the upland areas around the Bida Ridge and flows through Landzun Ward, from which it derives its name. It meanders southwestward across low-lying terrain, passes near the Federal Polytechnic Bida, and continues toward smaller tributaries that ultimately connect to the River Kaduna system. Consequently, the stream forms part of the Niger Basin catchment, which drains into the River Niger, one of West Africa's major river systems.

The region receives an average annual rainfall of approximately 1,100–1,300 mm, occurring mainly between May and October, while the dry season extends from November to April. Annual temperatures range between 25 °C and 35 °C, influencing the hydrological regime of the stream, with elevated water levels during the rainy season and reduced flow or near stagnation during the dry season [15]. Landzun Stream plays a vital role in the socioeconomic activities of the Bida populace, providing water for domestic use, irrigation, washing, and small-scale fishing, and functioning as a storm-water runoff channel during periods of heavy rainfall.

However, increasing urbanization, indiscriminate waste disposal, and encroachment along the stream corridor have resulted in pollution and sedimentation, adversely affecting water quality and aquatic life [20].

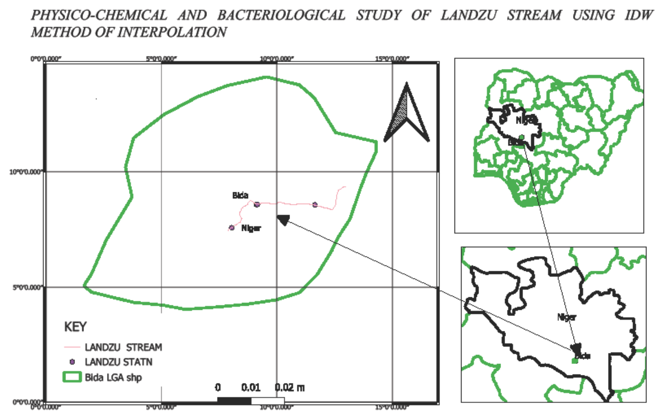

Figure 1: Map of the Study Area

Sample Collection

Water samples were collected at each sampling location using the grab sampling technique and transferred into sterile 500 mL polyethylene bottles. Prior to fieldwork, all sampling containers were thoroughly washed and rinsed with distilled water. Sterile amber-coloured glass bottles were used for bacteriological analyses, while clean 1-L plastic bottles were used for physicochemical analyses. Samples were preserved during transportation in an icebox containing ice packs.

Sampling site coordinates were recorded using a Global Positioning System (GPS) device with an accuracy of ±3 m. In-situ measurements of pH, temperature, dissolved oxygen (DO), and electrical conductivity (EC) were obtained using a multi-parameter probe to ensure accuracy and minimize changes during transportation [5]. Additional field measurements were conducted using a pH meter for acidity/alkalinity, a DO meter for oxygen concentration, a conductivity meter for electrical conductivity, a turbidity meter for water clarity, and a digital thermometer for temperature determination.

Strict aseptic procedures were maintained throughout sample collection to prevent bacteriological contamination. To obtain representative samples, collection bottles were submerged below the water surface. All bacteriological samples were immediately preserved in an icebox with ice packs and transported to the laboratory within six hours to maintain sample integrity [5]. Marker pens and waterproof labels were used for proper sample identification, while sterile gloves and face masks were worn to ensure hygienic handling during sampling.

Analysis of Physicochemicals and Biological Properties of the Water Samples

The physicochemical parameters analysed included pH, temperature, turbidity, electrical conductivity (EC), total dissolved solids (TDS), dissolved oxygen (DO), biochemical oxygen demand (BOD), nitrates (NO_3^-), and phosphates (PO_4^{3-}). In-situ measurements of pH, temperature, EC, and TDS were carried out using a portable multi-parameter meter. Turbidity was determined using a nephelometric turbidity meter, while DO and BOD were analysed using the Winkler method. Nutrient concentrations (nitrates and phosphates) were determined spectrophotometrically in accordance with standard procedures outlined by [5].

Bacteriological quality was assessed by analysing *Escherichia coli* and total coliforms. The Most Probable Number (MPN) per 100 mL of water was determined through presumptive, confirmed, and completed tests following standard microbiological procedures [6]. The presence of *Escherichia coli* was confirmed based on gas production and characteristic colour changes in selective culture media using the multiple-tube fermentation (MTF) technique.

Spatial analysis of water quality parameters was conducted using ArcGIS version 10.8 through the Inverse Distance Weighted (IDW) interpolation method. This deterministic technique assumes that sampling points closer to the prediction location exert a greater influence on estimated values than those farther away [9]. A fixed search radius was applied, and the power parameter was set to 2 to ensure consistency. IDW was selected due to its computational simplicity and suitability for environmental datasets with irregular sampling distributions [20].

Data analysis

Data analysis was performed using Microsoft Excel and SPSS version 25 to compute descriptive statistics, including mean, minimum, maximum, and standard deviation. GIS-based IDW outputs were further analysed to identify spatial patterns and potential pollution hotspots. The results were compared with national and international drinking water quality standards, including the Nigerian Standard for Drinking Water Quality and World Health Organization [18] guidelines.

ESULTS

pH values at Station A varied from 5.69 ± 0.08 to 6.91 ± 0.20, as shown in Table 1. At the upstream station, the stream water was slightly acidic; downstream, it was almost neutral. The sampling stations' temperature values, which ranged from 30.07°C to 30.17°C, were comparatively steady, suggesting a uniform thermal distribution that was probably influenced by the surrounding climate. The range of calcium hardness was 19.60 ± 0.37 mg/L to 40.75 ± 16.81 mg/L, the range of magnesium hardness was 2.21 ± 1.03 mg/L to 2.57 ± 0.06 mg/L, and the range of total hardness was 21.96 ± 0.19 mg/L to 42.96 ± 16.19 mg/L.

Table 1: Physicochemical Parameters of Landzun Stream

sample name	Ph	Temperature (°C)	Mg Hardness (mg/L)	CaHardnes (mg/L)	Total Hardnesn (mg/L)
Station A	5.69±0.08a	30.17±0.06a	2.57±0.06a	19.60±0.37a	21.96±0.19a
Station B	6.44±0.084b	30.13±0.06a	2.43±1.06a	25.38±14.05a	27.82±13.74a
Station C	6.9133±0.20c	30.07±0.12a	2.21±1.03a	40.75±16.81a	42.96±16.19a

Three bacterial species were found in the water samples, according to the bacteriological analysis (Table 2) namely: *Escherichia coli* (*E. coli*), *Shigella spp*., and *Klebsiella aerogenes*. Different levels of bacterial contamination are indicated by their distribution and incidence rates. With three appearances, or 42.9% of all isolates, *Shigella spp*. had the highest frequency of occurrence. *Klebsiella aerogenes and E. coli* each appeared twice, accounting for 28.5% of the total isolates

Table 2: Frequency of Occurrence of the Bacteria Isolates in Landzu Stream

Bacterial Isolates	Frequency	Occurrence (%)
Klebsiellaaerogenes	2	28.5
Shigellaspp	3	42.9
E. coli	2	28.5
Total	7	100

Table 3 shows the presumptive test results across the three stations in Landzu Stream. The Most Probable Number (MPN) method was used to estimate the number of coliform bacteria present in a water sample. This process involves three stages: presumptive, confirmed, and completed tests [6]. In the presumptive test, different dilutions of the water sample are inoculated into lactose broth tubes—double-strength lactose broth (DSLB) for 10 mL, single-strength lactose broth (SSLB) for 1.0 mL, and 0.1 mL—to detect gas and acid production, which indicate potential coliform presence. The number of tubes showing positive results for gas and acid formation is used to determine the coliform count in terms of MPN/mL.

Samples that were positive in the presumptive test were inoculated into Brilliant Green Lactose Bile (BGLB) broth to confirm the presence of coliforms. A "+" sign indicates confirmed presence, while a "–" sign indicates absence [6]. To verify whether the confirmed coliforms are of faecal origin, selective media such as Eosin Methylene Blue (EMB) agar or MacConkey agar are used. A "+" indicates faecal coliforms are confirmed (like *E. coli*), while a "–" indicates no faecal coliforms were detected [6].

Table 3: Tube fermentation of the water sample/MPN/confirmed and completed Tests.

Water Samples	Presumptive Test Number of Positive Tubes			MPN/ml of Coliforms	Confirmed test for Coliforms	Completed test for Coliforms
	3 tubes DSLB 10ml	3 tubes SSLB 1.0ml	3 tubes SSLB 0.1ml			
Station A	2	1	1	20	+	-
Station B	3	1	0	43	+	-
Station C	3	1	0	43	+	-

Table 4: Microscopic and Biochemical Characteristics of Bacteria Isolated from water sample in Landzu Stream

Water Sample	Characteristics												Tentative Bacterial Identity
	Microscopic		Biochemical										
	Gram Reacti	Shape	Catala se Test	Gas	Indole Reacti	Spore Stain	Oxidas e Test	Citrate Test	Manni tol	Glucos e	Lactos e	Sucros e	
Station 1 A	-	Rods	+	+	-	-	-	+	+	+	-	+	*Klebsiellaaerogenes*
Station 1 B	-	Rods	+	+	-	-	-	-	+	+	-	-	*Shigellaspp*
Station 2A	-	Rods	+	+	-	-	-	-	+	+	-	-	*Shigellaspp*
Station 2B	-	Rods	+	+	-	-	-	+	+	+	-	+	*Klebsiellaaerogenes*
Station 3A	-	Rods	+	+	-	-	-	-	+	+	-	-	*Shigellaspp*
Station 3C	-	Rods	+	+	+	-	-	-	+	+	+	+	*E. coli*
Station 3B	-	Rods	+	+	+	-	-	-	+	+	+	+	*E. coli*

GIS Maps indicating various physicochemical parameters along Landzu

GIS Maps indicating various physicochemical parameters along Landzu

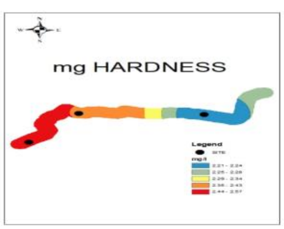

Figure 2: Showing Mg Hardness mapping in ArcGIS 3.34.

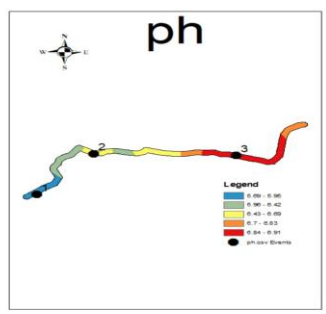

Figure 3: Showing pH mapping in ArcGIS 3.34.

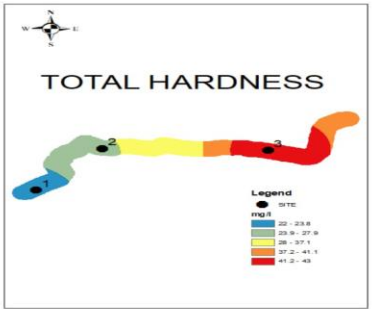

Figure 4: Showing Total Hardness mapping in ArcGIS 3.34.

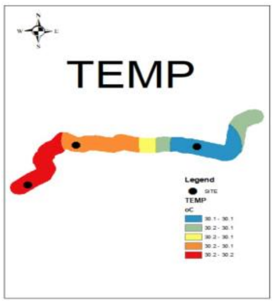

Figure 5: Showing Temperature mapping in ArcGIS 3.34

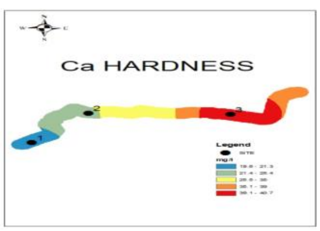

Figure 6: Showing Ca Hardness in ArcGIS 3.34

DISCUSSION

The breakdown of organic materials and runoff from adjacent agricultural lands could be the cause of the somewhat acidic pH found in the upper portion of Landzu Stream. [16] state that streams close to farms frequently exhibit lower pH levels as a result of humic and fulvic acid leaching. The pH values in Landzu Stream (5.69–6.91) are similar to those reported by [12], who found that surface waters in Niger State had pH values between 5.8 and 7.2, suggesting similar geochemical impacts.

The findings of [2] who discovered that tropical freshwater bodies in Nigeria retain relatively steady temperatures due to limited depth and intense solar exposure, are consistent with the temperature stability throughout the sampling stations. The stream's moderate microbial activity and nitrogen cycling are supported by the average temperature of about 30°C [13].

WHO acceptable limits for surface water were fulfilled by the hardness criteria (calcium and magnesium). On the other hand, the increase in total hardness downstream (42.96 mg/L) suggests that runoff or natural rock breakdown may have contributed to the mineral enrichment. This observation is consistent with the findings of [10], who found that anthropogenic discharge and sediment deposition caused the Kaduna River's downstream parts to become harder.

E. coli, *Shigella species*, and *Klebsiellaaerogenes* are indicative of faecal contamination and unsanitary conditions in the Landzu Stream catchment. One of the main markers of faecal pollution, *E. coli* is frequently associated with contamination from human or animal waste [4]. Comparable bacterial profiles in water samples from Bida streams were reported in similar investigations, such as [17] study, which revealed high coliform levels above WHO guidelines.

In contrast, lower coliform counts were found in a study by [11] on the bacteriological quality of surface waters in Anambra State. This suggests that the level of contamination in Landzu Stream is higher, perhaps as a result of increased human activity and improper waste management near the watercourse.

This study's results are consistent with those of [20]. who found that physicochemical factors like pH and hardness had a major impact on bacterial survival in aquatic environments. The findings of [19] that tropical freshwater systems with near-neutral pH and moderate hardness promote microbial persistence, especially coliform bacteria, are also supported by our work. The findings, however, differ from those of a research by [8], who attributed bacterial predominance mostly to nutrient enrichment rather than mineral composition and found no significant link between hardness and bacterial load in the Awka River. The discrepancy can result from variations in the hydrological dynamics and land use of the regions under study.

Spatial differences in pH, hardness, and bacterial dispersion were shown by the IDW interpolation maps (Figures 4.1.5.1 to 4.1.5.5). Higher hardness and coliform concentrations were found in the central and downstream regions, which were associated with agricultural activity and communities. [20]. GIS-based evaluations, which emphasised the use of IDW as a trustworthy method for visualising water quality gradients in contaminated Nigerian streams, are consistent with this spatial pattern.

Conclusion Although the water's physicochemical properties were largely within acceptable bounds, the presence of pathogenic bacteria indicates significant contamination that makes the water unsafe for direct human consumption without treatment, according to the physicochemical and bacteriological analysis of Landzu Stream. Bacterial persistence is facilitated by the steady temperature, mild hardness, and acidic to nearly neutral pH range. The geographical patterns of pollution were effectively visualised by the GIS-based IDW interpolation, which confirmed that the intensity of contamination increased as the stream moved downstream. This emphasises how important it is to continuously monitor and use GIS technologies for pollution control and water quality management.

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